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April 28, July 6 and July 7, 1916. From compairsons with Polar Standards it appears that the range of variation is in excess of a magnitude. At maximum the star is photographically fainter than magnitude 16.5. It is, therefore, probably the faintest variable star so far discovered.

HARLOW SHAPLEY.

ON THE OBSERVED ROTATIONS OF PLANETARY NEBULÆ.

Our spectrographic observations for the detection of evidences of rotation in the brighter planetary nebulæ, reported upon in these PUBLICATIONS, Vol. 28, pp. 119-20, June, 1916, have been continued during the summer and fall months. We have tested nearly forty planetaries. About twenty give definite evidence of rotational motions, or relative motions within the nebulæ. For a half dozen others we suspect that the nebular lines are inclined to their normal directions in some cases and distorted from straightness in others, as Doppler effects resulting from motions. In about fifteen cases no indications of rotation or relative motion within the nebulæ have been found.

In general the larger planetaries, and in general the nebulæ whose elliptic outlines have the greatest eccentricities, give the strongest evidences of rotation or internal motion.

The smallest nebulæ and the nebulæ whose outlines are most nearly circular are the ones in which the tests for rotation have failed. Failure with very small nebulæ may arise from the difficulty in guiding with sufficient accuracy throughout the long exposures, and, in the case of the circular, to the possibility that the axis of rotation is pointed approximately toward the observer. It is apparent that in the latter case the spectrographic method cannot hope to succeed.

A number of the ring nebulæ give lines of such form as to suggest that the observed phenomena result from a combination of rotational motion and other type or types of motion. We are not prepared to interpret the phenomena, but in certain cases a motion of nebular materials toward the central nuclei of the objects is at least suggested, and for other nebulæ the complications seem to be due to absorption of the materials composing the outer strata of the nebular structures.

The observations indicate in general that the outer strata are rotating more slowly than the inner strata, both angularly and linearly. This is, in effect, a lagging behind of the outer strata.

Measures of the rotational velocity of a nebula enable us to draw some interesting conclusions concerning its probable mass. Assuming that a particle of material in a nebula at a given angular distance from the center is moving in obedience to the gravitational force of the central mass, in accordance with Newton's law, then, if the central mass is assumed to be equal to the mass of our Sun, we should find that the maximum position distances of the ten or twelve nebulæ whose observed motions are interpretable as rotations lie between 250 light-years and 5 light-years. Such small distances are improbable, in view of evidence of other kinds. If we assume that these nebulæ are at distances of 1000 light-years, which we think is a more probable order of distance, the minimum values of their masses, in terms of the Sun's mass, lie between 4 and 210.

As we have remarked earlier, it is difficult to avoid the conclusion that the so-called ring nebulæ, which are so plentiful amongst the planetaries, are in reality not ring forms in space, but ellipsoidal shells. If these forms are rotated about the minor axis of figure, which also seems highly probable, it is difficult to account for their apparent equilibrium under the usual rotational and gravitational forces: it would seem that the nebular materials in the polar regions—the regions at the extremities of the rotation axes—should be depressed toward the central nuclei. Are other forces, possibly including radiation pressure, involved?

Inasmuch as the observer will not in general be situated in the planes of the equators of rotation of the nebulæ, the observed rotational velocities must be smaller than their true values. On this account, the actual masses of the observed nebulæ should be greater than the minimum values assigned above. The effect of any radiation pressures would likewise make the deduced masses smaller than they are. The indications are that the nebulæ under consideration are capable of developing into something analogous to our solar system, but much more massive than is our solar system.

W. W. Campbell,
November 20, 1916. J. H. Moore.

Recent Improvements at the Lick Observatory.

Minor injuries to a large section of the west outside wall of the main building resulting from the severe earthquake of July, 1911, came prominently to sight in the past winter, and repairs were necessary. Advantage was taken of the situation to combine improvements with repairs. The north room of the main building has up to the present time contained five astronomical clocks. These clocks were of the highest class obtainable at the time of their purchase, three decades ago, but they are now surpassed in excellence by modern clocks. Our chief dependence in recent years has been upon the Riefler constant-pressure clock, mounted on a stone pier within a separate masonry chamber constructed in the basement of the meridian circle house. We have this summer enclosed and given finish to a room of considerable size in that basement, with the Riefler clock chamber in one corner of the room. The Dent sidereal clock and the Frodsham mean-time clock have been moved from the old clock room to a suitable enclosing chamber in the new room. One Hohwü sidereal clock from the old clock room has been mounted in a new protecting case on one of the strong piers in the meridian observing room. The other Hohwü sidereal clock has been transferred from the old clock room to the observers' room at the Crossley dome. The Howard mean-time clock has been moved to a new protecting case near the intersection of the corridors of the main building, where it is in convenient position for members of the staff and community, and where the visiting public may compare their watches. The old clock room has been converted into an astronomer's office. The large office, known to all members of the staff, past and present, as the Assembly Room, has been divided into two offices. The north wing of the main building now contains four large offices, each with two windows. It has always been difficult to heat the old offices on